More Issues of Building Energy Simulation

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Abstract: The paper investigates the development of building energy simulation software. It is shown that such applications can be used for energy forecasting, system design and operations, and energy evaluation. Several energy simulation methods are analyzed and compared, and the predominance of the Z-transfer function method is indicated on dynamic calculation of energy consumption of heating and air-conditioning systems. The paper discusses the means to deal with several complex problems, such as thermal bridge, external sunshade, and meteorological data.

Key words: building energy simulation; simulation; thermal bridge; meteorological data

1. INTRODUCTION

Building environment is determined by outside climate condition, radiation status of heat sources inside and ventilation. So, to make sure building environment keep comfortable and meet other standards, the control system should also be adjusted with the change of building environment condition. Because the change is a complex process influenced by many factors, numerical simulation on computer must be used to forecast it more effectively.

2. DEVELOPMENT AND APPLICATION STATUS OF BUILDING ENERGY SIMULATION TECHNOLOGY

Currently, lots of foreign and homemade applications are used on simulation and analysis for building thermal environment. Among them there are many widespread and authoritative ones, such as DOE2.1E, BLAST, ENER-WIN, Energy10, TRNSYS, HOT2 XP, SPARK, ESP-r, DeST and so on.

Building energy simulation software is applied widely on three main aspects bellow.

2.1 Forecasting and Optimization on Building Energy

When heat preservation of outer wall, capability of outer window or window-wall ratio is improved, or different thermal inertia wall is selected, building inside thermal environment and energy consumption will change other. Because it is hardly to analyses, directly and exactly, relation between such measures and the whole-year energy of building, dynamic calculation hour by hour should be taken. Numerical simulation is often adopted to evaluate environment status and energy effect of a design project, and to optimize the design, for some restricting each other relations will change with climate and indoor environment.

2.2 Forecasting Capability of Air-Conditioning System

Actual air-conditioning system runs in many meteorological conditions and indoor used ways. Mostly, it is not running at extreme cold or extreme hot points as designed initially, but between them. Because the conditions and characteristics of this part of load are always different from each other, so the system often shows some problem, for example, it may not satisfy the environment control requirement, and it may make cold and heat kill each other, which would increase the energy expense. Through dynamic simulation of whole year, all kinds of conditions and problems in running system will be find out, and effective measure can be taken on system, structure and control project. Besides, simulation can also forecast whole-year air-conditioning energy of different system design; thereby system design and

equipment collocation can be optimize accordingly.

2.3 Evaluation of Building Energy

America is one of the first countries to study energy efficiency of building, and the application of computer technology in America is also flourishing. After the energy sources crisis in 70s of 20 century, Canada, another North America country, began to pay attention to study on energy efficiency of building and the application of computer technology on evaluation of building energy. Many European countries developed their simulation software which has brought biggish economic and societal benefit in actual application. The development and popularize of these applications can evaluate building energy qualitatively and quantificationally, make it easier to actualize the criterion of building energy saving, and improve the perfect and development of criterion itself.

The standard system of building energy efficiency in china is still in seedtime. The audit work of energy using of building has not began, and integrated evaluation on energy efficiency is just a blank. Most national software was developed aiming at improving the efficiency, veracity and more scientific of project design, but it is deficiency to synthetically evaluate energy of finished building.

On July 1st of 2005, "design standard of commonly building" was implemented. To respect architects' creativity, keep variety of buildings' appearance and fashion, and make the design accord with the standard at the same time, balance judgement[1] was introduced to estimate whether thermal performance of building meet the requirement. Dynamic calculation of whole year energy should be taken on audit work using capability index, which must be carried out depending on special computer software.

3. ANALYSIS OF ARITHMETIC

At present, there are many adaptable analysis methods about building energy. They are classed into two types depend on their mathematic model: one type is static method, and the other one is dynamic method.

Static method includes degreedays, bin, charge-frequency list and equative full charge runtime method. These methods are simpler compare to dynamic method, and cannot simulate whole year energy accurately. Dynamic method considers all kinds of factors more accurately and achieves exacter result. Three popular methods have been used by existing software to calculate 8760 hours' energy of whole year. They are response coefficient, z-transfer function and heat-balance. Several dynamic methods are introduced below.

3.1 Finitude Difference Method

Finitude difference method is a popular numerical method to solve heat transfer problem. Many heat transfer models are hardly or impossible to achieve parse results, so discrete way is employ to get approximate results.

For example, heat transfer of wall can be deal with by one-dimension model for its longness is far bigger than its thickness. This method is very simple, but its workload is very big other.

3.2 Harmonic Method

Harmonic method describes weather condition, which changes instantly but presents periodicity in general, by progression of sine or cosine function, and changes it into Fourier spread series. The heat flux can be calculated if indoor temperature and outdoor changing meteorological condition have been known.

Because weather shows randomicity, and especially while indoor temperature would also change with time, it is not suitable to use harmonic method to calculate the unsteady heat transfer of building.

3.3 Response Coefficient Method

The basic idea of response coefficient method includes three steps. Firstly, the disturbance factors' curves changing continuously are dispersed into cell disturbance which distributes in time sequence. Secondly, the response coefficients of thermal system to unit cell disturbance are calculated. Finally, response coefficients are used to get the final results

by integral.

Response coefficient method is a bran-new method compare to other traditional ones. It was transplanted to heat transfer of building from auto control theoretics. One benefit of the method is that it disparts heat characteristic of system from outside disturbance, so the method considers that response coefficient is a thermal characteristic of system itself and is foreign to outside disturbance. If only response coefficient and instantaneous and historical value of outside disturbance have been known, the heat flux at that time can be achieved. Therefore, it is very convenient to analyses building energy using hourly meteorological data directly.

3.4 Z-transfer Function Method

Z-transfer function method is an improvement of response coefficient method. Because z-transfer function relates to disperse system theory, it can be considered as a special method. This method uses swatch data and z-transfer to solve the condition while in and out data both are disperse value.

Laplace transform which deals with continuous system is applied in z-transfer function method. Heat transfer system is a disperse system actually. Response coefficient method has dispersed the issue by triangle pulse analysis before do inversion. While z-transform is included which is used to deal with disperse system, the base of transfer function method is established[2].

Compress format of transfer function, of which response coefficient is just one special case, can be get using z-transform. The format can quicken calculation speed and save more memory space and more calculate time. Take heat transfer of wall for example, the biggest excellence of transfer function method is that it can dispose expediently the boundary condition which is changing discretionarily. The heat flux of wall can be achieve simply while both indoor and outdoor temperatures change continuously, which is very important to solve dynamic load case with long periods.

3.5 Heat-balance Method

Heat-balance method bases on thermodynamics' first law. This method confirms some control systems for inside and outside surfaces of building and indoor atmosphere, founds heat-balance equations respectively and joins them into a group. Temperatures of the control systems can be got to calculate the equation group, and energy can be calculated with these temperatures. Heat-balance method is more exact to get instantaneous load, but the calculation needs much more time.

According to the analysis above, it is suggested to adopt z-transfer function method to simulate whole-year hourly load energy of heating and air-conditioning system. Besides, heat-balance equation group must be found with which z-transfer function method can be combined to calculate nature indoor temperature.

4. DISCUSSION OF SEVERAL COMPLEX QUESTIONS

4.1 Thermal Bridge

In recent years, along with the development and advancement of building energy efficiency, many new types of construction material have been used in buildings, and efficient heat preservation materials have been applied into structure. Therefore heat resistance of wall's main section increases greatly while wall's thickness keeps the same or even becomes thinner. What's more, local heat bridges appear at the node parts of building, because heat preservation material has been cut off to meet the intensity demand of structure. Thermal bridge is a great factor to building energy and heating index, and effect degree change with building structure. To get more reasonable simulation result, all types of thermal bridges should be taken into account.

Thermal bridge include inside and outside wall angle, four sides of window, construct columniation and girder, balcony, roof , floor angle and so on. Two-dimensional or three-dimensional heat transfer model must be introduced to deal with thermal bridge, which will expend much memory and time to calculation. However, most common applications of building energy simulation, take DOE2，TRNSYS，BLAST ， CODYBA6.0 for example, adopt

one-dimensional model to simulation heat transfer of wall, which cannot consider the effect of thermal bridge.

4.2 Hourly Meteorological Data of Typical Year

Typical year is a data year composed by a series of hourly meteorological data, which is very important to simulate whole-year energy of building well and truly. The data mainly includes 14 types of hourly meteorological parameter. They are outdoor dry-Bulb temperature, outdoor damp-Bulb temperature or dew point temperature, atmosphere pressure, cloud condition, cloudage, relative humidity or absolute humidity, outdoor atmosphere enthalpy, outdoor atmosphere density, wind speed, wind direction, illumination of solar direct radiation, illumination of solar dispersion and rainfall and snowfall.

The most familiar method is experience method brought forward by Hall[3]. The method employs Filkenstein Schafer[4] measure to compute and select meteorological data of 12 typical months, which compose the typical meteorological year, from the data of many past year. In final result, dry-Bulb temperature and statistic and continuity structure of everyday solar radiation have been considered. Different authority gene is selected to do calculation for typical meteorological year of different city or area.

4.3 Heat Transfer Coefficient of Outside Surface of Wall

At present, most applications choose a fixed value to heat transfer coefficient of outside surface, and any others use two different coefficients for winter and summer. In fact, the coefficient changes greatly with outdoor weather condition. So dynamic coefficient should be confirmed depend on wind speed and material of wall, for they are the two main factors to the coefficient. However, it is hardly to find out such arithmetic, especially calculation of surface wind speed is very complex.

4.4 External Sunshade

To calculate the effect that external sunshade makes on solar radiation on window is a complex dynamic process. On the one hand, the altitude and azimuth angle are changing all time, and outside weather is changing other, which make solar radiation and shadow area of external sunshade on window change with them. On the other hand, solar radiation includes direct and dispersed radiation, and illumination of each direction is different. Most popular software adopts approximate means to deal with the external sunshade.

Coefficient of external sunshade is an average one. That fixed external sunshade establishment affects the quantity of solar radiation getting in room is considered through whole calculation period of heating or air-conditioning. The coefficient relates to local geography, direction of window and so on.

4.5 Outside Window

The rate of direct radiation and dispersed radiation cast on outside window changes with time. The transmission ratio and absorptivity to solar radiation will show much difference, if glass changes different thickness, different type or different layer number. And user of software may not have or will not like to import parameter information of glass window. So it is suggested that calculation of outside window be deal with more simply, and that coefficients of external and internal sunshade are introduced.

4.6 Door

Door can be deal with in the same way as wall. And it can also be calculated directly using heat transfer coefficient taking no account of its little capability of saving heat.

4.7 Roof

The shape and gradient of roof is various, so total radiation reaching to it is very different from each other. It should be deal with seriously while do simulation.

4.8 Floor and Basement

Floor, underground wall, outside fundus and part of wall over floor should be calculated separately.

Centre part of floor can be found model as half infinity unsteady heat transfer model, and be calculated with z-transfer function method while taking no account of atmosphere layer of outside surface and taking underground soil's temperature as the temperature of outside surface, for temperature often keeps steady under 2.4 deep. Around part of floor and underground wall can be calculated approximately using some experience coefficient, because temperature of soil changes with depth and outside condition and it is hardly to calculate accurately. Outside fundus can be considered as one thermal bridge or be neglected.

4.9 Nature Indoor Temperature

Nature indoor temperature is used in many aspects. Firstly, hourly room temperature of whole year can be known without air-conditioning. Secondly, while doing simulation, disturbance of air-conditioning system can add to the temperature directly, so it need not to calculate nature temperature repeatedly, no matter how enactment value of room changes. Finally, to try to meet room enactment, magnitude of disturbance from air-conditioning system should be calculate and add to nature indoor temperature, and load of system will be achieved well and truly.

5. CONCLUSIONS

The application of simulation software of building energy is quite prevalent abroad, but it is very little in China. The standard system of building energy efficiency in china is still in seedtime. The audit work of energy using of building has not began, and integrated evaluation on energy efficiency is just a blank. Most design process is still following traditional load calculate method. Lots of measures to control and adjust air-conditioning system are very blind. The function and effect of several only existing homemade applications is not satisfying.

Therefore, two issues, research and application, must be solved validly and successfully. On the one hand, some complex problems which affect the capability of software must be deal with availably and in reason. On the other hand, to popularize these applications, correlative policy and laws should be constituted and perfected, responsibility and academic and technical level of related professionals should be enhanced and improved.

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